FY96

RESEARCH

TECHNOLOGY AREA PLAN

HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE & TECHNOLOGY
WRIGHT PATTERSON AFB, OH

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RESEARCH

VISIONS AND OPPORTUNITIES

The mission of Air Force basic research is to sponsor and sustain basic research, to transfer and transition research results, and to support Air Force goals of control and maximum utilization of air and space.

Only a vigorous, focused, and diversified basic research program can provide our Nation with the required depth and scope of options for new and advanced technologies to meet the air and space superiority goals of the Air Force. Furthermore, the relative decrease in planned acquisition of new weapon systems makes it imperative to rely more on a partnership with the U.S. industrial base, logistics support and the operating Air Force. This focus of basic research not only strengthens the ability of U.S. firms to meet defense needs, but also contributes to the ability of U.S. industry to succeed in world competition and international markets.

To this end, Air Force basic research has adopted the vision to build partnerships with excellence and relevance. Its key ingredients are technology transition partnerships and laboratory partnerships. Their objective is to increase success and speed of technology transfer and transition while maintaining our long-standing high standards of highest quality research. Our partnerships approach fosters integration of Air Force, university and industry researchers with customers in acquisition, the operating Air Force and U.S. industry; most importantly, the in-house 6.1 tasks at the Air Force laboratories are intensely connected with the 6.2 and 6.3 efforts within these laboratories. Such Laboratory Partnerships are the cornerstone which enables the in-house components to become focal points for technology transition from the extramural research community. Last year, our nearly 2,000 active research tasks spawned more than 300 significant technology transitions to Air Force 6.2/6.3 programs, to U.S. industry and to other customers within and outside of DOD.

Of critical importance to the Air Force as well as the Nation are programs aimed at enhancing our most precious resource--human talent. These programs focus on the creation of new technical research talent and the enhanced use of existing talent. This includes provisions for undergraduate and graduate student research, fellowships for graduate students, and postdoctoral assignments at Air Force laboratories. In addition, university faculty are sponsored in summer programs as well as for sabbaticals at Air Force laboratories. Furthermore, Air Force researchers are sponsored to visit and work at highly reputed laboratories in the U.S. and overseas. Strong emphasis is given to assure full participation of minorities and minority institutions in these efforts.

Our interface with the international science and technology community through our offices in London, UK, and Tokyo, Japan concentrates on access to foreign laboratories by our researchers, on collaborative efforts, and, most importantly, on covering the full spectrum of all Air Force science

and technology for customers in Air Force laboratories as well as product, test, and logistics centers.

This Technology Area Plan (TAP) reflects AFOSR's commitment to preserve and strengthen the national knowledge base and research infrastructure in support of the Air Force goals of global reach and global power. We leverage the Air Force science and technology investment; we transition research results to users in the Air Force and in U.S. industry, and we produce world-class, militarily significant and commercially valuable technology advances.

This plan has been reviewed by all Air Force laboratory commanders and directors, and it reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.

RICHARD R. PAUL
Brigadier General, USAF
Technology Executive Officer

HELMUT HELLWIG
Director, Air Force Office
of Scientific Research

CONTENTS

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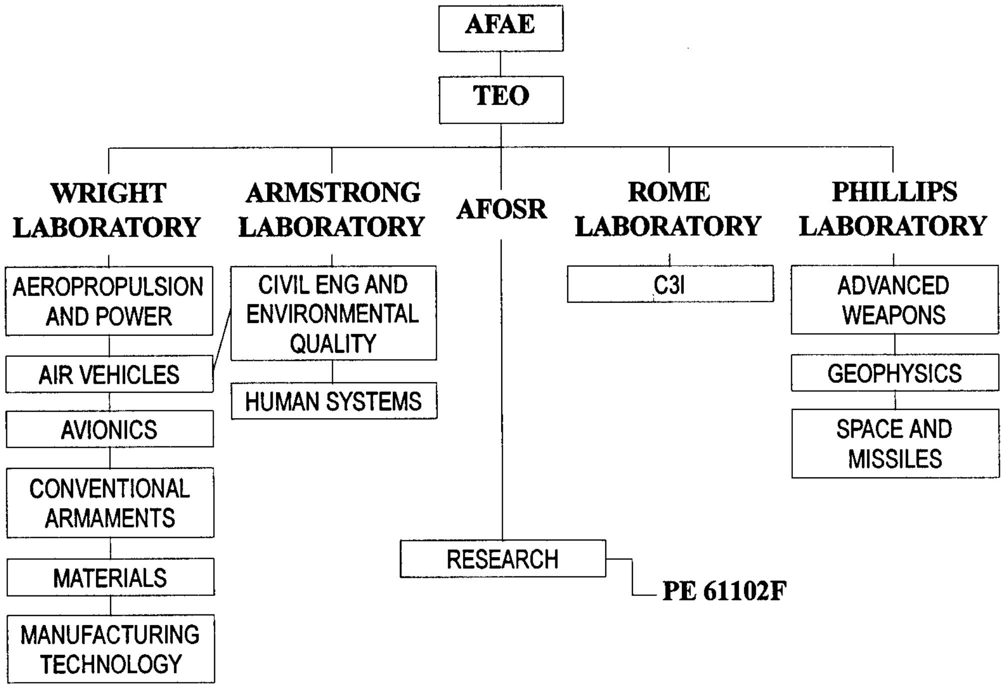


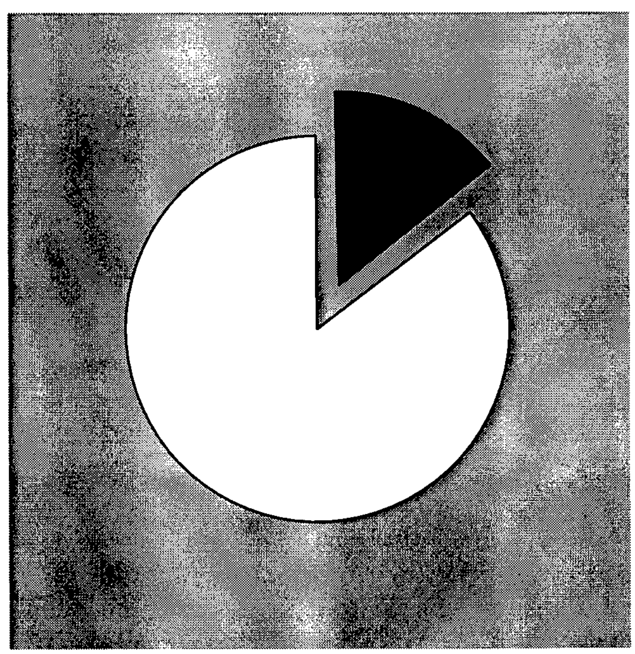
Figure 1. Air Force S&T Program Structure.

INTRODUCTION

BACKGROUND

The research technology area encompasses all Air Force (AF) basic research. It includes all scientific and engineering disciplines contributing to the Air Force mission. The basic research outlined in this plan will set the stage for the Air Force to perform its mission into the 21st century. The research technology area's goals are to

- maintain technological superiority in the areas relevant to Air Force needs;
- prevent technological surprise to our Nation and create it for our adversaries;
- maintain a strong research infrastructure of universities, U.S. industry and Air Force laboratories;
- complement the national research effort; and
- transfer and transition research results to users and customers.



Estimated AF S&T Budget
for FY 1996: $1.406B

Figure 2. Research S&T vs AF S&T.

With its proud tradition of over 40 years, the Air Force Office of Scientific Research is charged with directing the Air Force's basic research program. Through grants to universities, contracts for industry research, and support for basic research in Air Force laboratories, AFOSR forges the base for future Air Force strength. These research programs, funded at about $239.6 million for FY 95, consist of approximately 1400 extramural grants and contracts to about 450 academic institutions, industrial firms, and government laboratories, as well as about 125 intramural research efforts in the four Air Force laboratories.

Our support of basic research has not only served Air Force goals directly, but also contributed to a wide spectrum of scientific breakthroughs: during the past 40 years, the Air Force has provided basic research funds to more than 20 U.S. researchers who, as a result of the funded work, were later awarded Nobel Prizes.

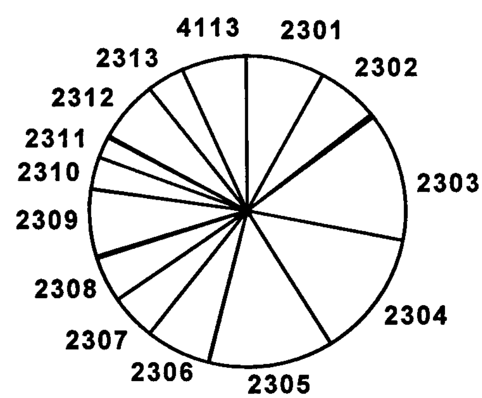
AFOSR has sponsored research that has found its way into the core of performing the Air Force mission. The following is but a small sample of these important contributions. The laser, a critical component of the precision-guided munitions used so successfully in Operation Desert Storm, was fostered in 1957 by a member of AFOSR. Advanced weather models have improved the efficiency of target acquisition systems and greatly enhanced the ability to communicate in combat conditions. Research in aerodynamics has resulted in improved jet engine compressors that have revolutionized fighter aircraft performance and range. The pilots of these aircraft have benefited from the knowledge gained in life sciences research, which has expanded the G-loading envelope in which they can effectively operate. The Kalman Filter revolutionized the area of estimation through the application of statistical filtering theory. Problems in space communication systems were bridged by the creation of the Viterbi Decoding Algorithm which provided a decoding solution to a variety of digital estimation problems resulting from electronic noise interference in transmission signals.

The basic research program is divided into thirteen scientific projects and one educational project. Project designations and titles are:

AFOSR's Research Projects

Project	Title
2301	Physics
2302	Solid Mechanics and Structures
2303	Chemistry
2304	Mathematical and Computer Sciences
2305	Electronics
2306	Structural Materials
2307	Fluid Mechanics
2308	Propulsion
2309	Terrestrial Sciences
2310	Atmospheric Sciences
2311	Space Sciences
2312	Biological Sciences
2313	Human Performance
4113	Science and Engineering Education Programs

The relative distribution of Defense Research Sciences (DRS) funds for these projects is shown in Figure 3 based on the FY 96 President's Budget Request. The program described in this TAP is subject to change based on Congressional action.



Estimated Research S&T Funding
for FY 1996: $239.6M

Figure 3. Major research thrusts (projects)

Other programs such as ARPA, BMDO, URI and SBIR provide additional resources for basic research. They are fully integrated into the programs described in this TAP and ensure the broadest possible scope of our research and its ultimate relevance and utility.

AFOSR has identified 15 Core Technologies of importance to the Air Force. AFOSR Core Technologies are defined as those technologies where AFOSR has made substantial investments and where AFOSR-sponsored research is critical, leading, or even dominant on a national scale. For each Core Technology, the scientific disciplines and research issues that need to be addressed to advance the core technology have been linked with the customers, users, and beneficiaries of the core technology. In view of the complexities (many disciplines, very different customers) and the nonlinear nature of these linkages (6.1 often feeding directly into operations), the Core Technologies are the AFOSR basic research taxonomy for making management, priority and investment decisions. We believe that only technology advances (not just discipline advances) provide tangible customer benefits.

AFOSR Core Technologies

Structural Integrity
Structural Materials
Airbreathing Propulsion
Rocket and Space Propulsion
Aerodynamics and Hypersonics
Real Time Avionics
Optical Computing and Storage
Optical Countermeasures
Signatures and Surveillance
Precision Strike
High Power Microwaves
Space Weather Prediction
Hazard-Free Operations and Maintenance
Intelligent Systems for Selection and Training
Sustained Human Performance

Core Technologies thus represent AFOSR's approach to manage technology advances through coordinated research in several disciplines for the benefit of our customers; they represent the road maps for basic research.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

RESEARCH IN AIR FORCE LABORATORIES: Approximately one-third of our research program is carried out in Air Force laboratories. These include the four major laboratories: Armstrong, Phillips, Rome, and Wright. These intramural basic research programs contribute significantly to the Air Force's, as well as the Nation's, research efforts. One-third of the intramural research teams have been identified as leading the international community in their chosen fields of study. Through our concept of Laboratory Partnerships the intramural efforts enable effective transitioning of research results from the extramural research programs and the national and international research community to the Air Force science and technology programs. In addition, intramural basic research attracts and retains world-class scientists and engineers. Thus, this intramural basic research program gives the Air Force substantial benefits and leverage:

- World-class contributions to the Nation's research base.
- Talent pool for future Air Force technology leaders and managers.
- Contributing to the talent pipeline by hosting high school, undergraduate, and graduate students from all social and ethnic backgrounds.
- Interface with the national and international community, attracting visiting scientists and guest professors, and hosting workshops.
- Transitioning of research results to the Air Force and its industrial suppliers from the national and international science and engineering communities.

Guided by our Core Technologies, intense interaction between AFOSR's research program management and the S&T thrusts performed in the Air Force laboratories assures relevance and timely response to Air Force needs. Formal feedback, generated during reviews in the fall and spring of each year, is used to determine the direction of our research, and to enhance the transition to DOD 6.2 and 6.3a efforts, as well as directly to U.S. industry.

RESEARCH IN INDUSTRY: Industry, especially the aerospace industry, interacts with Air Force basic research in several ways:
Independent Research and Development (IR&D): Streamlining to compete in the global economy, U.S. companies have drastically cut research ex-

penditures. Interface to Air Force sponsored university research and the Air Force laboratories now, more than ever, provides U.S. industry with access to new opportunities as well as with information helpful in addressing Air Force technology needs and opportunities. AFOSR maintains this interface through an intense dialogue with more than ten major U.S. industrial research laboratories and by providing access for U.S. industry to our research results and data bases; this includes not only DTIC but also AFOSR's electronically accessible data bases.

Contracted Research: Several percent of DRS funding directly supports basic research performed by U.S. industry. These efforts allow access to unique facilities, laboratory capabilities and special skills of industrial research teams. AFOSR's management of contracted research emphasizes corporate support through integration of research efforts into the contractors' planning process. This active approach to technology transfer stimulates interest in IR&D among firms with little or no research involvement and leverages industrial basic research programs that might otherwise not respond to long term Air Force needs.

Small Business Innovative Research. The AFOSR budget for SBIR projects will decrease from \$7.5M in FY 95 to \$7.1M in FY 96. The program will continue to focus on Phase II projects that have potential for commercialization. The goal is to convert 60 percent of the current Phase I projects to Phase II projects this year. The Small Business Technology Transfer Program (STTR), which was established by Congress in FY 94, remains somewhat stable. The STTR program funds research performed by a partnership that includes a small research firm and a research institution. In FY 96, \$2.0M of the \$7.1M identified in the SBIR program will be available for grants under the STTR program. The STTR program emphasizes projects with commercial potential. The STTR program, like the SBIR program, is a two phase program with one exception. STTR Phase I awards are up to \$100K for a 12 month effort and Phase II awards are up to \$500K for a 24 month effort.

RESEARCH OVERSEAS: Today a large portion of research advances occur overseas, although, on a per capita basis, the United States continues to lead the world. Since 1990, overseas inventors, mostly European and Japanese, have filed more than half of all new U.S. patents.

To fulfill its mandate of assuring future technological superiority, the Air Force basic research program must respond to these developments and provide effective access to research advances overseas. To this end, AFOSR maintains foreign offices in London, UK, (the European Office of Aerospace Research and Development) and in Tokyo, Japan (the Asian Office of Aerospace Research and Development). Both offices are staffed with senior researchers drawn from the Air Force S&T community. In addition to a number of liaison activities, the primary focus of these offices is collaboration and technology transitioning. Their customers, historically the Air Force laboratories, increasingly include the logistics and test community and other Air Force and DOD agencies. Their means of fostering collaboration and technology transition include participation in the scientific and engineering communities of all nations at meetings, workshops, and seminars; detailed technical reporting, as well as analysis, and summary reports; and briefings and seminars at Air Force organizations. Special programs bring hundreds of eminent researchers from foreign laboratories to Air Force and DOD organizations for lectures and working visits. A special program permits senior Air Force researchers to perform studies at leading foreign laboratories. These latter programs provide access to advanced foreign techniques for Air Force laboratory efforts.

In addition, AFOSR, in cooperation with its overseas offices, carries out technology assessments. The former Soviet Union is especially interesting. But countries of special importance include the U.K., Japan, France, Germany, Israel, Korea and China. Reports summarize the state-of-the-art as practiced by named researchers at identified laboratories, describe the intended applications for this research, and provide an assessment of the openness of the laboratories to collaborative research with appropriate Air Force scientists and engineers.

MINORITY PROGRAMS: For Historically Black Colleges and Universities (HBCU) and Minority Institutions (MI), two significant new programs have started in FY 95. The first program is the Future Aerospace Science and Technology (FAST) Centers which is a part of a DOD infrastructure support program designed to help develop research and development capabilities at HBCU/MIs. Six areas of interest were selected: 1) Fault-Tolerant Distributed Computing for Command Control Communications and Intelligence (C3I), 2) Cryoelectronic Signal Processing, 3) Lightweight Structural Materials and Processing, 4) Structural Integrity of Aerospace Systems, 5) Environmental Remediation, Fate and Transport of Hazardous Chemicals, and 6) Infrared Surveillance and Countermeasures. Each institution will be supported over a six year period subject to availability of funds. The second program, AFOSR Scholars Program Integrating Research and Education (ASPIRE), is an upcoming AFOSR program designed to increase the number Ph.D. candidates in mathematics, science and engineering at HBCU/MIs.

CHANGES FROM LAST YEAR

Due to manpower reductions, AFOSR had to reduce its total positions from 216 to 143 by September 1995. This reduction is being accomplished by closing the Frank J. Seiler Research Laboratory; eliminating Engineer and Scientist Exchange Program positions; eliminating foreign liaison positions (Ottawa and Paris); and reducing AFOSR core staff by 26 positions at Bolling AFB.

Project 2303, Chemistry, reorganized the Inorganic Material Chemistry subarea into the Surface Science subarea to advance technology in novel lubricants and lubrication systems and corrosion chemistry.

Project 2304, Mathematical and Computer Sciences, restructured to address modeling for use in Command and Control systems and artificial intelligence approaches to yield more powerful approaches to planning, designing, and modeling.

Project 2307, Fluid Mechanics, merged Internal Fluid Dynamics into External Aerodynamics and Hypersonics, and Turbulence and Internal Flows. This reorientation provides focus on unsteady flow issues for aerodynamic lifting surfaces and control applications.

Project 2313, Human Performance, merged Spatial Orientation and Perception and Recognition subareas to create a new focus on sensory systems with implications for improvements in human-machine and sensors technologies.

IMPACT OF DEFENSE RELIANCE

Basic research programs and management are formally coordinated with DDR&E and with the Army, Navy, ARPA, and BMDO. In addition to day-to-day scientific exchanges by S&T leaders from each Service, formal working groups and procedures exist. DDR&E carries out annual reviews and monthly coordination meetings. A memorandum of understanding between the Army Research Office, Office of Naval Research and AFOSR is in effect. This memorandum establishes joint planning and funding, as well as coordination of collocated foreign field offices. Scientific Planning Groups are operating in twelve disciplines to execute long-range research planning and technical reviews. Furthermore, the Scientific Planning Groups interface with and support the Defense Reliance Technology Area Plans of the 6.2 and 6.3a programs. A comprehensive Basic Research Annual Report, issued jointly by the three Services details the technical areas of cooperation and Service uniqueness in three levels of breakdown as well as last year's coordination, resource shifts, and joint achievements.

PROGRAM DESCRIPTION

PROJECT 2301, PHYSICS

This project provides the fundamental knowledge needed to conceptualize and develop new advanced Air Force weapons systems. It also establishes the basis for many additional technologies such as Avionics, Aerospace and Propulsion. Research in physics often has found application in fields of electronics and related technologies: e.g., performance improvements of lasers have carried over into propulsion system diagnostics or atmospheric study tools; into industrial semiconductor processing or Air Force medical applications. While the users and customers may differ, fundamental principles underlying desired functionality are the same and require detailed understanding to model and predict performance goals. The Physics program is jointly planned and executed within the three Services. This program is also coordinated with ARPA, particularly on a recent ARPA initiative in vacuum electronics. Results of these well integrated efforts have transitioned to industry, such as HPM tube concepts transitioned to Hughes.

A major technology goal of the Optics Research is to find lasers (excluding semiconductor lasers) exhibiting power, efficiency, wavelength, beam quality, and modulation formats that satisfy future Air Force requirements in the general areas of threat countermeasures and information processing and storage. Another major goal is in imaging space objects and in directing high energy laser beams through the atmosphere using adaptive and nonlinear optical techniques. A third goal is to obtain x-ray laser optics for x-ray imaging and beam formation. Customers for these programs in laser and electro-optical technical development, and in optical and infrared countermeasures are the Wright and Phillips Laboratories. Coordination with other services and ARPA is maintained by serving on joint review panels or, by joint funding, for example at Hughes and Rockwell. ARPA's Optoelectronic Materials Research Centers serve as major technology coordination and transfer mechanisms. These provide formal technology demonstrations and industrial collaborations for numerous results achieved by AFOSR funded research.

Physics

- Plasma Physics
  - -- Microwave/Plasma Interactions
  - -- Vacuum Electronics
  - -- High-Power Microwaves
- Atomic and Molecular Physics
  - -- Metastable Species
  - -- Collision Plasma Effects
- Photonic Physics
  - -- Ultrafast Effects
  - -- Semiconductor Lasers
  - -- Photochemical Materials
- Optics
  - -- Non-linear Optics
  - -- Near-field Optical Effects
  - -- Adaptive Optics
  - -- X-Ray Optics

Photonic Physics aims to make available semiconductor lasers and laser arrays with characteristics needed in optical information storage and display (large area and helmet mounted), in wideband communication systems, in manufacturing inspection systems, and in medical diagnostics. High power arrays for threat countermeasures are also a major goal. Other major goals of this program are to advance electronic technology to speeds several orders of magnitude beyond what is available today, and to create new beam processing technologies that can lead to dramatic advances in microelectronics and micromechanics. Customers are the technology programs at the Wright, Rome, and Phillips Laboratories. Coordination with other services and ARPA, and industrial interaction is maintained by the mechanisms described above.

Atomic and Molecular Physics research is directed toward understanding of interactions of atoms and molecules related to time and frequency physics and to upper atmosphere modeling. Accurate models of interatomic

interactions will be used to make GPS clocks smaller and more accurate and to predict upper atmospheric processes affecting communications, surveillance, and remote sensing from space. This latter program has helped to establish reliable levels of background emission and demonstrate the imaging capability that is to be used in the Space and Missile Systems Center's Defense Meteorological Satellite Program. Data on etchant species will be provided to revise industrial plasma reactor models (SEMATECH). A program of containing antiprotons and their use to create a strong neutron flux for space effects simulation and controlled reactions is conducted in close cooperation with Phillips Laboratory.

Plasma Physics seeks fundamental understanding of collective interactions of charged particles with electromagnetic fields in order to drive advances in communications, radar, low-observables, materials processing, and directed energy weapons. A major theme in this subarea is the push for more efficient, compact, tunable, and reliable electron-beam-driven sources of microwave radiation. In satisfying the needs of Rome and Wright Laboratories, this program emphasizes sources offering higher frequencies and broader bandwidth. A key element of this research effort is the new Center for Advanced Research on Air Force Millimeter-Wave Physics (successor to the Advanced Thermionic Research Initiative) located at the University of California/Davis. That center, along with the other university efforts, boasts extremely strong ties with major U.S. microwave electronics firms such as Varian Associates and Litton Electron Devices. This university/industry cross-fertilization is further enhanced through close cooperative ties to the Tri-Service program in Vacuum Electronics. An additional major beneficiary of the above research efforts is the high power microwave (HPM) weapons-related R&D efforts studied jointly with the Phillips Laboratory. Additional research thrusts examine the effects of plasma on microwave signals and novel concepts related to the use of atmospheric-pressure plasmas in industrial materials processing.

PROJECT 2302, SOLID MECHANICS AND STRUCTURES

This project seeks to develop a fundamental understanding of the behavior of aerospace materials, structures, and supporting facilities, leading to the cost-effective development and safe, reliable operation of superior weapons and defensive systems.

Solid Mechanics and Structures

- Mechanics of Materials
  - -- Fracture Behavior of Materials
  - -- Ceramic-Matrix Composites
  - -- Internal Damage Growth Mechanics
  - -- High Temperature Materials
- Particulate Mechanics
  - -- Constitutive Behavior of Particulate Materials
  - -- Effects of Microstructures
  - -- Shear Localization and Instability
  - -- Flow in Porous Media
- Structural Mechanics
  - -- Failure Prediction
  - -- Adaptive Materials and Structures
  - -- Aeroelasticity System Behavior
  - -- Structure-Control Integration

Research in solid mechanics and structures is necessary for the design and operation of future Air Force weapon systems as well as the continuing operation of existing systems, which are currently projected for use well beyond their original design lifetimes. Research includes such diverse topics as the micromechanical design of advanced materials, modeling and simulation of the dynamic behavior of aircraft, missiles, and large space structures, and the technology integration for performance and survivability enhancement of these systems. Under Reliance, the Air Force has the lead responsibility for the mechanics of high-temperature structural materials and particulate material systems and fixed-wing aeroelasticity. Research also covers such areas as nonlinear structural dynamics and control, structural inelastic behavior, intelligent materials and structures, and environmental quality research. The Army has primary responsibility for research in impact/penetration mechanics, and rotary-wing aeroelasticity, while the Navy is the lead service in the mechanics of thick-section composites, structural acoustics,

and hydroelasticity. This project, then, provides the only direct DOD 6.1 mechanics and structures technology support to the design and operations of USAF aircraft, missiles and spacecraft.

Future aerospace engine and airframe structures will be composed of advanced, high-temperature composite materials capable of extended operation in severe environments. The development of these materials will allow the design of faster, more efficient aircraft and spacecraft. These advanced materials are also enabling technology for planned hypersonic weapons and aircraft, which can potentially take off from conventional runways and achieve global orbit. Current project thrusts include the thermomechanical behavior of high-temperature polymer-matrix composites, metal-matrix composites, intermetallics, structural ceramics, and carbon-carbon composites. Scientific issues include improved fiber/matrix interfaces, durable coating systems, and improved design methodology and life prediction systems based on material damage mechanisms. Results from this research have been used by Rockwell International to design interfaces for titanium aluminide (TiAl) composite turbine engine compressor rotors, and to develop metal-matrix composite damage accumulation models for Boeing's High Speed Civil Transport (HSCT) program. AFOSR researchers are also studying innovative new material systems, such as functionally-graded materials and nanostructural materials.

Since traditional solid mechanics principles do not capture the fundamentals that dictate the behavior of advanced, composite material systems, the study of structural behavior also includes expansion of the fundamental knowledge base to better understand the deformation and failure of aerospace structures. The anisotropy, inhomogeneity, and damage characteristics of emerging structural material systems dictate the development of new solid mechanics and structural analysis principles critical for performance prediction and material synthesis. Wright Laboratory successfully used the damage mechanics and life prediction methodology developed at the University of Illinois to assess structural integrity and improve the design of the F-16 canopy. The extended service life for many existing systems also requires further research to understand how materials and structures behave after very long periods of service. Factors such as corrosion and multiple-site damage serve to reduce the load-carrying capability of aging Air Force aircraft. Georgia Tech researchers have been working closely with WR-ALC to apply the composite repair technique for C-141 weep holes. New methods of nondestructive evaluation of these systems are also being sought to detect internal cracking and/or corrosion in a quick and reliable manner. The mechanics research sponsored in this project is closely coordinated with research performed under Project 2306, Structural Materials, which considers the materials science and processing aspects of modern aerospace structural material systems.

This project also seeks to develop a fundamental understanding of the behavior of simple and complex particulate materials based on first principles. Examples of particulate materials include metallic and ceramic powders used for manufacture of advanced aerospace materials, asphalt cement concrete used in airfield pavements, and solid rocket propellants. Theoretical, experimental, and computational studies are being conducted on idealized and actual particulate materials. A fundamental knowledge base is sought to develop analytical models for the evaluation of material handling and processing methods. The output of this research will aid in the design and analysis of aerospace systems and their supporting facility infrastructure.

This project also seeks a fundamental understanding of nonlinear vibration and acoustic behavior of airframe and engine structures along with an understanding of the dynamic behavior of space structures. These nonlinearities trace to the interaction of fluids and structures, large amplitude vibration, system nonlinearity due to damping, and other phenomenon. The result of this research is expected to provide engineering information on airframe failure from fluid flow

disturbances and engine stall due to pressure variation. Researchers in the universities are working with Wright Laboratory and Aeronautical Systems Center (ASC) on these operational problems. Coupling nonlinear dynamics principles with advanced materials development, fluid mechanics, control theory, and sensor/actuator development, this research leads to the development and design of real-time monitoring and self-correction techniques for enhancing system performance. For example, intelligent materials and structures are being developed which can continuously monitor damage formation and growth in current and future aerospace structures. Continuous shape control of aerodynamic surfaces may also be possible through the placement of systems of sensors and actuators at critical points within the structure. One of the objectives of this research is to provide answers to many system operational issues. Examples include limit cycle oscillations and flutter on fixed-wing aircraft, engine compressor instability and turbine failure, and spacecraft vibration and control.

PROJECT 2303, CHEMISTRY

Research in chemistry fills current and projected requirements of two principal Air Force technologies: materials and energetics. This project provides the fundamental knowledge needed to meet the increasing demands for materials with advanced properties, affordable cost, and environmentally benign processing. Achieving the required material properties, such as strength, durability, toughness, service temperature and lifetime, spectral response, and corrosion resistance, increasingly requires control of structure and composition at small levels, sometimes approaching fewer than hundreds of atoms and molecules. Areas of emphasis in materials chemistry include properties and processing of polymers, corrosion resistance, friction and wear, and the chemical and biochemical transformations which aerospace materials undergo in the environment.

The technology of energetics seeks to efficiently control the conversion of one form of energy to another. Transformation of stored chemical energy finds application in propulsion, munitions, lasers, and as a source of signatures of aircraft and spacecraft. Advances in space propulsion are sought by developing materials with high energy density and controllable stability. Research on molecular energy redistribution in condensed, inhomogeneous systems will produce effective, but insensitive, explosives for safe storage. The detection and surveillance of space systems are achieved through the understanding of the detailed light emitting chemical reaction in the exhaust plume in comparison with counterpart reactions of the background atmosphere.

Polymer chemistry is one area of emphasis. The objective in this area is to advance the organic and polymeric materials technologies by providing the knowledge needed to create new properties for Air Force applications and to utilize the materials in a fashion that will yield more durable and affordable systems. Emphasis is on polymers with nonlinear optical properties for photonic applications. The knowledge generated in this work is continuously transitioned into development programs of Wright Laboratory, ARPA and BMDO. Research in polymer chemistry includes extramural research and in-house research at Phillips and Wright Laboratories. This work focuses in four areas: nonlinear optical polymers, multifunctional polymers, ceramers, and organic superconductors. Nonlinear optical polymer research seeks new chemical structures for enhancing processibility and optical nonlinearity. Theoretical chemistry methods predict the required molecular electro-optic properties for such polymers. The software implementing these methods is being adapted for commercial release. Multifunctional polymers combine different desirable properties in a single polymer molecule. This research will lead to materials for advanced sensors, and "smart" devices and structures. Ceramers, alloys of ceramics and polymers, combine the desirable properties of two important classes of materials to yield a new class of material for a broad range of lightweight applications ranging from photonics to structures.

The scientific objectives in surface science involve tribochemistry, chemical sensors, and chemical corrosion. This will provide the Air Force technological pay-offs in novel lubricants and lubrication systems, coatings for space vehicles, and non-destructive evaluation and inspection of aircraft components. This work supports technology requirements of the Armstrong, Phillips, Rome, and Wright Laboratories. In-house research is conducted at all four laboratories. This program supports subterranean sensing for the Air Force environmental clean up program. Significant technology transfers in the past year included the production of polyhedral oligomeric silsesquioxane (POSS) polymers for Thiokol Corporation's rocket motor insulation. Theoretical calculations now elucidate the prevailing atomic interactions at the interface as one metal moves across the surface of a different metal. Recent experimental work supported by this program shows a step doubling of Ni (977) crystal surfaces in the presence of small amounts of oxygen immediately prior to bulk oxidation. This may lead to diagnostic tools to alert technicians to impending corrosion on aircraft, and thereby prevent its occurrence. Transfer of tribology technology includes advanced coatings for ball bearings, dental drills, and plating applications.

Chemistry

- Polymer Chemistry
  - -- Nonlinear Optical Materials
  - -- Multifunctional Polymers
  - -- Ceramers
- Chemical Reactivity and Synthesis
  - -- Enzymatic Processes
  - -- Advanced Materials Chemistry
  - -- Biomimetics Synthesis
- Surface Science
  - -- Tribology
  - -- Chemical Sensors
  - -- Corrosion Chemistry
- Molecular Dynamics
  - -- Atmospheric Chemistry
  - -- Energetic Materials
  - -- Chemical Lasers
  - -- Interactive Dynamics
- Theoretical Chemistry
  - -- Molecular Properties of Non-linear Optics Polymer

The effect of Air Force materials and processes on the environment is an increasingly important area of chemical research. Research in chemical reactivity and synthesis aims at advanced materials with significantly improved properties, lower cost preparation, and positive environmental impact. Investigations include chemical and biochemical transformations which developmental aerospace materials may undergo upon release into the environment. Also being investigated are biochemical transformations which may have utility for low-cost biosynthesis/biomimetic synthesis of chemicals with potential application to aerospace materials, or which may shed light on corrosion processes which may impact aerospace materials.

Experimental and theoretical research in molecular dynamics aims at developing predictive capabilities for chemical reactivity and energy transfer processes and controlling these processes on a detailed molecular level. These capabilities will improve aircraft and rocket propulsion system design, detection and control of signatures and exhausts from aerospace vehicles, energetic materials for propellants and explosives, and high energy laser systems. The basic understanding developed here is transitioned to applied programs by close interactions between principal investigators, Air Force laboratory scientists, and representatives of industry. For example, the High Energy Density Matter program, run jointly with the Phillips Laboratory, studies energy storage and stability of molecules in order to produce novel propellants for spacelift. Theoretical chemistry research has saved enormous time and research money by eliminating trial-and-error synthesis of proposed HEDM materials which lack promise. Novel propellant additives developed in this program are currently being tested in collaboration with industry. An initiative on Insensitive High Explosives explores how energy localization affects chemical reactions in solids that control the sensitivity of explosives. Studies of the dynamics of ion-molecule reactions, reactions of atmospheric species, energy transfer, and gas-surface interactions support efforts to improve our understanding of processes that

produce radiant emissions in the atmosphere; affect communications, plumes, and signatures; and degrade materials in space. Research results are transitioned to many areas including predictive codes for radar cross sections (REACH), models of atmospheric radiance (FAUST, MODTRAN), spacecraft interactions (SOCRATES), and chemical lasers. Efforts to develop infrared chemical lasers are carried out with Phillips Laboratory for Air Force theater missile defense and countermeasure applications.

PROJECT 2304, MATHEMATICAL AND COMPUTER SCIENCES

This project provides advances in the mathematical and computer sciences that increase our capability to model, analyze, understand, and control complex systems and phenomena of Air Force interest and also increase our capability to utilize computing effectively. Requirements are ubiquitous throughout the Air Force as reliance on software and automation becomes widespread both in embedded applications, simulation and training, and for engineering design, and as requirements for increased systems performance drive us into more nonlinear and complex domains.

Our program in dynamics and control has the Tri-Services leadership role as well as a high level of national recognition. Research is leading to improved techniques in the design and analysis of new control systems with enhanced capabilities and performance. Applications include the development of robust feedback controllers for advanced high performance aircraft with new capabilities for battle damage mitigation, maneuverability and engine stall avoidance; the control of vibrations and the shape of large, flexible space structures; active control of wing camber using embedded smart sensors and actuators; the control of combustion and fluid flow processes associated with aerospace vehicles. Research emphasizes distributed parameter control, robust multivariable feedback control, and adaptive control. Recently novel interdisciplinary research has been initiated in nonlinear control to develop techniques for controlling fluid flow and combustion processes, as well as highly nonlinear coupled interactions between structural deformations and unsteady flows. Fundamental theoretical algorithms developed in this program have transitioned to production quality control design software (e.g., implemented in Matrix-X, Matlab, Ctrl-C, and Easy5) which is widely used by Honeywell and Wright Laboratory as well as other industries and DOD laboratories. A new initiative is aimed at developing technologies that permit the design and construction of aerospace vehicles with both low target signature and maximal performance.

Research in computational mathematics develops improved mathematical methods and algorithms to support Air Force scientific computing interests. It concentrates on supporting innovative methods and algorithms which enable the improved modeling, simulation, understanding, and control of complex physical phenomena. These phenomena include fluid flow, combustion processes, control of flexible space structures, nonlinear optics, directed energy weapons, high energy-density materials, crystal growth, and mesoscale weather modeling. Research in this subarea supports the national agenda in high-performance computing, including the exploitation of parallel computing. New and improved numerical methods are being developed including homogenization techniques, continuation methods, finite elements, particle and vortex methods, finite difference methods, ENO methods, spectral methods, and computational linear algebra, especially multigrid techniques. Recent progress in nonlinear dynamical systems, wavelets, and multigrid research is enabling us to develop new parallel multiresolution (or multiscale) algorithms with the capability for estimating the effects of neglected scales on those which are accounted for, in order to accurately predict the approximate long-time dynamics of a variety of dissipative systems of nonlinear partial differential equations (such as Navier-Stokes) over a broad range of physical scales, and to dramatically reduce the costs for computer simulations. A new initiative will develop the modeling and analysis methods as well as numerical techniques needed to bring

combustion processes into warhead design problems.

Mathematical methods in optimization and discrete mathematics are directed toward the solution of large or complex problems such as those occurring in logistics, engineering design, or strategic planning. When applied to Air Force transportation systems, these techniques result in the more efficient movement of men and material. We are also applying them to physical systems, specifically to the determination of molecular structures. This will enable prediction of material properties and the design of new materials. An initiative in Control of Discrete Event Dynamic Systems is starting to contribute to improved reactive planning applicable to theater battle management and manufacturing technology. Working with scientists at Wright Lab, we expect to transition results in this area directly to the manufacture of titanium aluminide rotor blades.

With the Air Force's increasing reliance on computers, it is important to develop systems that are efficient and reliable. Research into formal methods for software engineering addresses this concern. Formal methods involve the use of mathematics and logic as the primary element of software engineering; for example, using mathematical notation to specify the desired software product. This provides for the possibility of automatic (or semi-automatic) translation of the mathematical specification into executable code. One approach, tested at the U.S. Transportation Command, automatically generated transportation scheduling requirements from the Time-Phased Force and Deployment Data significantly faster than conventional scheduling systems. The growing importance of C^3I has resulted in a greater need for effective distributed processing systems for sharing information and computing resources. This program has Tri-Service leadership in distributed computing. Such research into real-time distributed systems provides means to effectively manage the complex interconnected military environment. A new initiative is aimed at developing dramatic improvements in command and control through the dynamic interplay between data processing and signal processing technologies.

Artificial intelligence research is pursued to enable computers to perform tasks not easily tractable by conventional computational means. Tasks include decision making under uncertainty and time constraints; computer-mediated training; object recognition; and distributed planning under dynamic conditions. Research in this area concentrates on machine representation of knowledge and reasoning methods. Logic, which has been the primary tool for the underlying theory, is being extended to be more encompassing and to overcome computational inefficiencies. The theory of geometric and algebraic invariants is being extended and applied to the area of target recognition. An underlying theory for autonomous systems operating in distributed environments is being developed. Research will be undertaken to combine and unify artificial intelligence approaches with operations research to yield more powerful approaches to planning, design, and modeling.

Research in physical mathematics pursues the development and interrogation of accurate mathematical models (mostly nonlinear partial differential equations) in a diverse collection of Air Force important areas including nonlinear optics (an area of Tri-Service leadership), materials science, inverse problems, and theoretical fluid dynamics. Equations describing electromagnetic wave propagation in nonlinear media are predicting stable operating regimes of semiconductor laser diode arrays. These lasers-on-a-chip can produce a substantial beam if properly orchestrated so that chaotic flickering and associated interference can be avoided. This work is in support of laser research at Phillips Laboratory. Similarly the nonlinear variational problems whose minima correspond to stable configurations of novel composite media and shape memory alloys have ushered in a new era in material descriptions and predictions. Smart skins and other useful designer materials are being explored at Wright Laboratory. The Air Force's emphasis on reliability and maintainability relies on credible and affordable

inspection. The mathematics of inverse problems speaks to these goals by identifying what is interpretable and delivering stable, accurate numerics. An example of theoretical fluid dynamics research which impacts Air Force and the civilian world is the elimination of wind tunnel wall interference effects during transonic test conditions. In contrast to both subsonic and supersonic tests, the wall interference is more grievous (test conditions can be encountered which correspond to no real flight conditions and the culprit is the tunnel wall) and the mathematical model is much more challenging. Results have already been reported to AEDC.

Electromagnetics research ensures effective exploitation of electromagnetic waves and devices. Propagation studies emphasize characterization of inhomogeneous and/or dispersive media with a description of the behavior of waves in such media. Propagation through dispersive media is being pursued in support of occupation and environmental health issues because human tissue is dispersive and rational attempts to determine microwave exposure standards must incorporate this propagation in penetration codes. The investment in electromagnetic scattering is driven by Air Force requirements in both target acquisition and detection avoidance. Large scale scattering computation is necessary for appraisal of radar coverage (theirs and ours) if realistic topography and atmospheric conditions (refraction) are accounted for. Also, prediction of the radar cross section for design or identification purposes requires extensive, rapid computation. A new initiative in high power microwave will improve our modeling capabilities for both wide band and narrow band somu design.

This project conducts basic research in statistical theory and in the treatment of transmitted information (signal processing). An array of techniques are pursued for communications, imaging, and with the goal of improving systems performance. Among the new mathematical approaches that have been beneficial in communications (identifying features in covert signals, compression of terrain following data links), and imaging (target recognition, advanced beam forming) is the wavelet transform and its generalizations. AFOSR has sustained an early

Mathematical and Computer Sciences

- Computational Mathematics
  - Reliable Numerical Methods
  - Novel Parallel Computing Strategies
  - Spectral Shock Capturing Techniques
- Electromagnetics
  - Computational Electromagnetics
  - Fast Multipole Methods
  - Propagation Through Dispersive Media
- Physical Mathematics and Applied Analysis
  - Inverse Problems
  - Mathematics of Materials
  - Non-Linear Optics
  - Theoretical Fluid
- Dynamics and Control
  - Robust Multivariable Feedback
  - Self-Designing Controllers
  - Distributed Parameter Control
- Systems and Software
  - Formal Methods
  - Distributed Systems Design
  - Parallel Computing
- Optimization and Discrete Mathematics
  - Linear and Non-Linear Programming
  - Intelligent Search
  - Optimization in Chemistry
  - Computational Geometry
- Artificial Intelligence
  - Knowledge Representation and Reasoning Strategies
  - Vision
  - Intelligent Tutoring
- Signal Processing, Probability and Statistics
  - Wavelet Methods
  - Communications
  - Reliability Analysis
  - Sensor Fusion

lead in Federal and world levels in this technology. Nonlinear science is making an impact by means of chaotic systems that generate covert signals, andin the design of robust, inexpensive analog to digital converters. Important progress has been made in extending imaging capability to a wide range (including SAR and millimeter wave) as well as the use of multi-resolution methods for modeling background terrain (which helps one quickly spot moving vehicles for example). Combined sensing (such as laser-radar/FLIR) necessitates advanced statistical methods ("data fusion") for their rapid interpretation to keep an edge in air combat. An emphasis on Bayesian methods, together with algebraic experimental design, makes it possible to get the most for every dollar spent on life testing of critical systems. AFOTEC has been using our input in this area.

PROJECT 2305, ELECTRONICS

Research in electronics supports a broad community of high technology customers in the fields of surveillance and communication and precision weapons and provides the fundamental basis for improving or developing future generations of Air Force electronic systems. Specifically, goals of this program are to use the entire electromagnetic spectrum for improving imaging resolution; to increase data and information processing speed in semiconductor, photonic, and superconducting systems for faster decision making; and to firmly control complexity, reliability and affordability. Research in this program is carried out to a substantial part at the Phillips Laboratory, the Rome Laboratories, and the Wright Laboratory, and aims at the discovery of innovative design options which are transitioned to the user community in the Air Force or to industry under Air Force contract. The Air Force and other services closely coordinate and plan research in electronics through the Joint Services Electronics Program and the Electronics Scientific Planning Group. The Air Force also leverages ARPA investments to support Air Force goals in areas such as high temperature electronics. The Joint Services Electronics Program (JSEP), in existence since 1946, is a mutual enterprise of the Army, Navy, and Air Force designed to provide the Department of Defense with a university-based research capability in electronics sciences and related areas. The objective is to support high risk, long-range, pioneering science in the areas of solid state electronics, quantum electronics, information sciences, and electromagnetic research in an interactive, interdisciplinary environment with strong emphasis on local leadership and minimal governmental oversight; to build productive partnerships between universities, U.S. industries, and DOD. Of twelve JSEP universities, the Air Force supports five with a strong emphasis on optical signal processing.

Research in Electronic Devices concentrates on approaches which promise greater frequency/speed of operation, greater bandwidth, lower power consumption, lower noise, and greater reliability in support of Air Force needs in guidance, surveillance, communications, electronic countermeasures, and electronic warfare. These approaches fall into two categories: the application of new semiconductor materials to existing electronic devices, and the development of entirely new device and material concepts.

The focus of Electronic Components and Circuits is the development of new and improved materials and components supporting such advanced Air Force systems as millimeter circuits and IR imaging systems. Important drivers are higher frequency of operation, higher power output, the integration into monolithic integrated circuits and improved reliability.

Research in Semiconductor Materials is directed toward developing advanced electronic and optoelectronic materials with emphasis on growth and characterization of semiconductors, radiation interaction with matter, and reliability problems associated with solid state devices. Efforts will develop new materials equilibrium and non-equilibrium growth techniques, such as molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD), for structures with applications in digital and microwave devices; high temperature electronics; ultraviolet to infrared detectors; solid-state lasers; waveguides; and displays and emitters. The major theme includes an atomistic, solid-state physics-based understanding of the materials science associated with such topics as heteroepitaxy, growth, and defects. Air Force laboratory Cooperative Research and Development Agreements (CRDAs) have facilitated major technology transfers.

Electronics

- Semiconductor Materials
  - -- Low Temperature Film Growth
  - -- Ultrafast Laser Interaction
  - -- Wide Bandgap Materials
- Quantum Electronic Solids
  - -- Superconducting Materials
  - -- Superconducting Magnetometry
  - -- Superconducting Electronics
- Electromagnetic Materials
  - -- Crystalline Non-Linear Materials
  - -- Optoelectronic Materials
  - -- Detector Materials
- Optoelectronic Information Processing
  - -- Optical Storage Approaches
  - -- Optoelectronic Computation and Interconnects
- Electronic Devices
  - -- Femtosecondary Processes in Semiconductors
  - -- Novel Transistor Concepts
- Electronic Components and Circuits
  - -- MMWave Components and Circuits
  - -- Spatial and Spectral Modulation
  - -- Far-IR Imaging Systems

Work on Electromagnetic Materials focuses on providing photonic materials and analysis support. Crystalline nonlinear materials and modulation materials are of interest. Bulk crystal growth techniques continue to be developed. Semiconductor material research is aimed at optoelectronics (especially infrared) with emphasis on use in fast, efficient electromagnetic applications such as in space and global communications, command, and control. Researchers recently achieved advances in optical communications with silicon-based optoelectronics. They are tranferring these results to the optoelectronics industry.

The Optoelectronic Information Processing topic pursues the insertion of optical and optoelectronic techniques into information processing systems, the capabilities of which range from parallel computing through image processing to signal processing. It supports device physics investigations that provide both the optical-electronic interface and the optical-environmental interface. Optical and optoelectronic devices perform data acquisition, transmission, interconnect, switching, and memory functions and support efforts in the use of photonics to achieve real-time adaptive signal and image processing capabilities.

The major thrust in Quantum Electronic Solids is to create new superconducting and other electronic material structures to enhance the ability to sense and manipulate observable information. The great virtue of superconducting electronics is that it can carry out the necessary functions faster, more sensitively, and with lower power dissipation--features which allow higher density of processing elements for a smaller instrument package. Recent discoveries of new classes of superconductors with transition temperatures above the normal boiling point of liquid nitrogen have created new opportunities to improving relevant physical and electronic properties of these materials and generated opportunities for creating devices with superior operating characteristics.

PROJECT 2306, STRUCTURAL MATERIALS

This research provides the basic knowledge for development of new materials to improve the performance, life-cycle cost, and reliability of Air Force systems. Direct goals of this program are to supply advanced materials that will increase the thrust-to-weight ratios of engines, reduce the weight of aerospace vehicle structures while increasing their performance, and control or eliminate advanced materials reliability issues. Emphasis is on monolithic metals, intermetallics and ceramics; metal, intermetallic, ceramic and organic matrix composites; and carbon-carbon materials. This program studies a broad range of material properties such as strength, toughness, fatigue resistance, and environmental resistance in airframe, turbine engine, and spacecraft applications. Research on processing methods is an integral component to the research on materials properties. Work in this project supports the technology goals of the Wright Laboratory Materials Directorate. Extramural researchers closely coordinate with the four research tasks at this directorate and one research task at the Phillips Laboratory Propulsion Directorate. The efforts in this project are also related to research being performed in Project 2302, Solid Mechanics and Structures. Close coordination of this project with the entire DOD basic research program in structural materials is being maintained through Project Reliance. Several jointly sponsored programs have resulted from this coordination process. Additionally, close coordination is maintained with industry R&D counterparts including Dow Corning, LTV, McDonnell Douglas, Rockwell, General Electric, and United Technologies.

Structural Materials

→ Metallic Structural Materials
- -- Metal and Alloys Used in Aerospace Applications
- -- Alloy Theory, Design and Experimental Verification
- -- Functionally Graded and Nanocrystalline Metallic Structural Materials
- -- Modeling and Processing of Interfaces in Metal Matrix Composites

→ Ceramics and Non-Metallic Structural Materials
- -- Related Processing, Structures and Properties
- -- Interface Control for Ceramic Matrix Composites
- -- Fundamentals of Fracture and Creep
- -- Oxidative Processes of Carbon-Carbon Materials

→ Organic Matrix Composites
- -- Environmental Effects on Polymer Matrix Composites
- -- Processing Science of Organic Matrix Composites
- -- Environmentally Safe Processing of Composites
- -- Carbon-Carbon Materials Processing

The goal of the research thrust in metallic structural materials is to provide the fundamental knowledge required for new metallic alloys and composites for aerospace applications. Potential applications of these materials will include turbine airfoils and disks, engine casings and nozzle components, airframe structural components, space and rocket propulsion components, and hypersonic vehicle skins. Improved metallic structural materials will be capable of higher operating temperatures at significantly reduced densities than currently available materials. These characteristics will result in increased thrust-to-weight ratios in gas turbine engines, lighter weight airframes, and will enable hypersonic vehicle technology. This includes development of materials to withstand temperatures up to and beyond 2100° F for turbine engines and hypersonic vehicle applications. This

will be accomplished through an understanding of relationships between processing, chemistry, structure and properties of metallic materials. Specific scientific topics include the development and experimental verification of theoretical and computational (atomistic) models, phase transformations, interfacial phenomena, strengthening mechanisms, plasticity, creep, fatigue, environmental effects, and the dynamic and static fracture of structural metallic materials. Materials under research in the metallic structural materials thrust include refractory metals, intermetallic alloys, metal matrix composites, intermetallic matrix composites, nanocrystalline metallics, functionally graded materials, and protective metallic coating systems. Efforts will be expanded into laminated microstructures and amorphous metallic alloys.

The objective of the ceramic materials research thrust is to provide scientific background for current and future applications of ceramics, ceramic-matrix composites, and carbon-based materials in Air Force systems. Ceramic materials are attractive for Air Force structural applications due to their capability to work at very high temperatures, their high specific strength and stiffness, and their high hardness that leads to excellent wear properties. Introduction of ceramic bearings in gas turbine engines and ceramic matrix composites for exhaust nozzles should lead to major improvements in thrust-to-weight ratio, efficiency, and signature characteristics of engines. In support of these applications this program emphasizes fundamental studies of high temperature properties of ceramic materials and their relationship to the atomic structure of constituting phases and to microstructure of the materials. Of particular importance are studies of oxide materials with large complex unit cells giving rise to high creep resistance. Also detailed studies of interfaces and interphases, their atomic structure, thermodynamic and mechanical characteristics, and their influence on the creep properties of ceramics are major components of this program. Currently, the research effort in interfaces concentrates on control of interfaces between the fiber and matrix in ceramic matrix composites. The goal is to lay the foundation for the development of tough, reliable ceramic matrix composites capable of working at temperatures above 2700°F. A variety of techniques for controlling oxidation resistance, thermal stability, and shear strength of interfaces are currently under investigation. In the area of carbon-carbon composites the program concentrates on designing new approaches for oxidation protection, such as protective ceramic films, oxidation-inhibiting dopants, and surface modifiers.

The goal of research in organic matrix composites is to provide the knowledge for lowering the life-cycle cost of using polymer matrix composites in Air Force systems. Additionally, improving the performance properties of these materials such as higher operating temperatures and improved compressive strengths after impact are important objectives. The program focuses on obtaining a better understanding of the mechanisms of property degradation in polymer matrix composites. This knowledge is important to implementing effective countermeasures during processing and deployment to prevent or decelerate performance degradation, and in reliably and accurately predicting the service lives of composite structures. The chemical and physical changes of the matrices, fibers and their interfaces will be investigated individually and collectively in a composite configuration to provide a better understanding of their influence on the property changes of composite structures. Another area addressed in this program is the environmentally safe processing of polymeric composite materials. Alternative processing methods and new material forms will be investigated to prevent undesirable releases of harmful chemicals to the environment, or to eliminate processing practices that are hazardous to the health of the workers. Solventless prepregging and neat powder resin prepregs are examples of these types of approaches.

PROJECT 2307, FLUID MECHANICS

Air Force basic research in fluid mechanics seeks to enhance the performance and reliability of aerospace vehicles by developing new capabilities for predicting and controlling the fluid dynamic and thermodynamic behavior of complex flows in flight regimes and propulsion systems affecting Air Force operations. This research seeks to

understand key physical phenomena, to develop methods and models to predict them, and to create innovative strategies to expand the boundaries of flight by controlling these phenomena.

Major thrusts include: 1) the development of computational methods for accurate and efficient numerical solution of the equations of fluid dynamics, especially for dynamic, unsteady, multi-body problems, 2) the aerothermodynamics of hypersonic flows, 3) the fundamental structure and dynamics of transitional and turbulent compressible flows, 4) the prediction and control of turbulent shear flows, 5) the dynamics of separating unsteady flow such as those occurring in rapid dynamic maneuvers at high angles of attack, and 6) the complex internal aerodynamics and thermodynamics of flows in gas turbine engines. These efforts closely couple with Air Force Laboratory 6.2 and 6.3 programs, primarily at the Wright and Phillips Laboratories. This project provides fundamental knowledge, data, concepts and tools for aerodynamic and aerothermodynamic prediction, design, test, and support. It directly couples with the needs of industry as well as Air Force Laboratories, Test Centers and Logistics Centers.

Aircraft and weapon systems in combat operate in environments far more hostile than those occurring under level flight. Weapons released in this environment have been known to hit the launch aircraft. Advanced Computational Fluid Dynamics (CFD) research is developing numerical simulation methods which predict the dynamic motion effects on aircraft systems and missiles. Research in multi-body CFD is developing computer simulation technology which can predict the trajectories of weapons as they release from an aircraft, reducing the danger to pilots who fly weapons certification tests. CFD research also focuses on understanding the fundamental causes of inlet unstart, the sudden shut down of engines on maneuvering supersonic and hypersonic vehicles. Results in advanced grid generation methods from research at Mississippi State University are now being used by McDonnell Douglas Aerospace in the F-15 program.

Future hypersonic flight vehicles will operate at very high altitudes within the earth's atmosphere to reach global targets. At these altitudes the atmosphere is highly rarefied, and there is no way to predict the character of these rarefied flows. Underpredicted drag and heat transfer can result in vehicles that will not reach their intended targets. Computational and experimental research aims at revealing the fundamental fluid mechanical properties of hypersonic, chemically reacting flow, providing better predictions of vehicle heating, directly leading to safe designs.

Aircraft manufacturers, Air Force labs and test centers require improved, validated turbulence models. In fact, such models top the list of industry needs for fluid mechanics research and are a key pacing item for computational fluid dynamics. Research targets the high Reynolds number, compressible flows of interest to the Air Force, and seeks to develop large-eddy simulation (LES) methods and improved subgrid turbulence models for accurate predictions. Recent advances at Princeton University using renormalization methods for turbulence models are now being used by Fluent Inc. and by Pratt and Whitney.

Fluid Mechanics

- External Aerodynamics and Hypersonics
  - -- Compressible Turbulence
  - -- Advanced Computational Fluid Dynamics
  - -- Hypersonics, Viscous Flows and Real Gas Effects
  - -- Fluid Structure Interactions, Buffet, and Flutter
  - -- Inlet Distortions and Compressibility Effects
- Turbulence and Internal Flows
  - -- Turbulence Modeling, Mixing and Transport
  - -- Prediction and Control of Turbulence
  - -- Unsteady Separation Mechanism
  - -- Flow Physics at High Reynolds Number
  - -- Compressor Instabilities, Role of Unsteadiness
  - -- Turbulent Heat Transfer Phenomena

Research aimed at controlling fundamental fluid dynamic behavior supports advanced technology development for a number of critical applications. When low observable requirements fix jet nozzle exit geometry, engine control optimization requires unconventional internal aerodynamic flow control strategies. Stealth configurations lack aerodynamic performance and need new fluid control approaches to support the development of advanced high lift technologies. Uncontrolled

sonic fatigue problems with the divergent nozzle flaps on the F-110 engine create one of the major headaches for logistics support of the F-16. Also, inadequate turbulent drag reduction strategies limit the potential for enhanced range and payload. Basic research approaches include innovative uses of microelectromechanical systems and neural networks, the generic issue being the management and control of vorticity production on aerodynamic surfaces. McDonnell Douglas is now exploring basic research results on jet control for supersonic jet noise reduction and fluidically controlled thrust vectoring.

A major concern of engine manufacturers, and the focus of the Integrated High Performance Turbine Engine Technology (IHPTET) Program is to improve the thrust to weight ratio of gas turbine engines. Improved compressor efficiency and stability are key elements of this requirement. Problems with heat transfer in the combustor and turbine stages account for half the ten-year development time currently required for new engines. In addition, thermally induced fatigue failures in the F-110 combustor produce one of the largest maintenance problems for the F-16. Research within this project aims at improving our understanding of heat transfer in high turbulence environments, improving film cooling, and controlling the unsteady fluid dynamics dominating compressor performance.

Current flight control systems intentionally limit the operational envelope of modern fighters to avoid entering the post stall environment during dynamic maneuvers. Unsteady aerodynamics research within this project seeks to develop the knowledge base to expand the predictability and controllability of flows in this environment. Another critical need is preventing the unsteady aerodynamic buffeting of vertical control surfaces on the F-15 and F-16 which leads to structural fatigue, loss of reliability and degraded supportability.

Under Reliance, this research program is closely coordinated with Army and Navy programs. AFOSR fluid mechanics research focuses on central Air Force interests in high speed flows, compressibility, dynamic maneuverability, control of aerodynamic phenomena, and the fluid mechanics and thermodynamics of flow in gas turbine engines. In turn, the Navy focuses on hydrodynamic wakes and free surface phenomena. In the area of unsteady aerodynamics, the Army deals primarily with 2-D blade-rotor interactions relevant to helicopters, while the Air Force focuses on 3-D vortex dominated fluid-structure interactions relevant to aircraft maneuverability.

PROJECT 2308, PROPULSION

Propulsion project conducts research applicable to all military air and space vehicular systems, including aircraft, tactical and strategic missiles, space launch vehicles, space vehicles, and future hypersonic systems. Advances in propulsion and energy conversion technology are essential to the increase in range, payload, speed, stealth, and supportability and decreases in cost of either existing or new vehicular systems. The payoffs include a 100 percent increase in range/payload for attack aircraft, a Mach 3+ capability in F-15 size aircraft, a 200 percent increase in payload to geosynchronous earth orbit and ramjet/scramjet operation to Mach 15-20.

Research falls into the areas of chemically reacting flow, non-chemical energetics, and diagnostics. The research effort is being conducted extramurally by both universities and industrial laboratories, such as those of United Technologies Corporation, McDonnell Douglas, and the General Electric Corporation and intramurally at Phillips and Wright Laboratories. Chemically reacting flows involve complex coupling between the rate of energy release through chemical reaction and the fluid processes which transport fuel, oxidizer, combustion products, and enthalpy. Non-chemical energetic systems include plasma propulsion for efficient orbit-raising space missions and efficient ultra-high energy thermionic systems for space-based energy utilization. Diagnostics research provides critically needed measurement capability for developing fundamental understanding and performance characterization of these processes such as spray and solid propellant combustion and plasma propulsion. For example, the sharp peaks obtained in the elastic scattering spectrum from high quality, minimum light leakage optical cavity are used to obtain real-time droplet diameter infor-

mation which has been used extensively in injector design for both gas turbine and rocket industries. In addition, elastic scattering spectrum can be used as a diameter-determining template of optical communication fiber during the fiber-melt pulling process.

Propulsion

Space Power and Propulsion
-- New, Clean, Highly Energetic Propellants Dynamics
-- Plasma Thruster Performance
-- Plumes and Contamination

Air-Breathing Combustion
-- Supersonic Combustion
-- Advanced Fuel Composition and Use
-- Ram Accelerator

Propulsion Diagnostics
-- Turbulent Reacting Flow Characteristics
-- Plasma Species in Combustors
-- Electric Fields in Flames

In terms of Air Force systems, the research in this project falls into several major thrusts which are hypersonic air-breathing propulsion; future hydrocarbon fuel utilization; combustion chamber compatible, clean, highly energetic propellants; high voltage/high power solar array systems; longer life cycle, highly efficient plasma thrusters; and high performance heavy launch systems. This research will develop computational design capability and efficient novel testing techniques to replace costly and lengthy trial-and-error propulsion system development methods. These new cost-effective design approaches will lead to improved performance, reduced maintenance time and costs, lower observables, and extended lifetimes of propulsion systems on Air Force aircraft, missiles and spacecraft.

On the request of the Arnold Engineering Development Center, AFOSR extended research on plumes and signatures to include ultraviolet radiation. Enhanced efforts in soot reduction and control studies will increase engine performance and to reduce aircraft signature and pollution. Research on turbulence-chemistry interactions in plumes is to seek chemical and fluid dynamic control mechanisms for improving signature characteristics and continue development of new, clean, highly energetic propellants with proper chamber and mechanistic compatibility to satisfy environmental concerns. Rocket combustion instability is being investigated by looking at the interactions among propellant combustion, rocket chamber dynamics, and heat transfer. An important new research thrust is advanced fuel composition and combustion. Advanced engines may withstand higher operating temperatures by using fuel as a coolant. After heating to a supercritical thermodynamic state, the fuel will not behave like liquid or gas and may form solid residues which will clog vital fuel system components. Research addressing this includes fuel formulation and its supercritical mixing and combustion characteristics, and the source of solids formation. New measurement techniques to characterize fuel-air mixing in both air-breathing and rocket chemical propulsion systems are being developed. Their techniques are essential to interpret system performance and to provide quantitative data to test the accuracy of computational design methods.

PROJECT 2309, TERRESTRIAL SCIENCES

The Terrestrial Sciences project supports fundamental research in seismology. This research seeks improved nuclear test monitoring capability necessary to effectively assess nuclear test ban treaty compliance, and to discourage nuclear proliferation by enabling first test recognition at low to moderate yield levels in regions where natural and man-caused seismic events may be prevalent. This research program is jointly planned through the Tri-Service Scientific Planning Group in Ocean, Geophysics, and Terrestrial Sciences. The other services have no programs in seismology and rely on the USAF for research in this area.

Terrestrial Sciences

Seismology
-- Detection and Event Discrimination
-- Event Location
-- Yield Estimation

This research program contributes significantly to the National effort to globally monitor compliance with international treaties, in particular the Comprehensive Test Ban (CTB). It provides the basic research required by and directly cooperates with the Subsurface NUDET Analysis Research

(SNARE) program for which DOE has the National responsibility to integrate National resources under common direction. This research feeds the focused research and the exploratory development programs of ARPA and the Phillips Laboratory in providing responses to the research needs of the Air Force Technical Applications Center (AFTAC) as expressed in the AFTAC Subsurface Research Plan.

University and industrial sector research focus on detection, discrimination, event location, and yield estimation. The major emphasis is to improve understanding of wave propagation characteristics and discrimination methodologies, including evasion techniques, in regions where nuclear weapons might be under development. In detection, research encompasses excitation of regional phases as affected by source depth and near source structure, and attenuation and scattering of phases along propagation paths. Location investigations include the recognition and use of depth phases for source depth determinations in various geological provinces for both teleseismic and regional cases. Discrimination research includes theoretical and empirical descriptions of seismic records generated by earthquakes, industrial explosions, mine tremors, and nuclear explosions from the same source regions. Research in estimating yield includes seismic coupling as a function of rock type and rheology, seismic spectral differences between explosions and other seismic events, and near-field shock-wave velocities and amplitudes. New algorithms for analyzing seismic wave velocity and the effect of Lehman discontinuity on the propagation path and velocity of seismic waves has transitioned to AFTAC for use in location analyses.

Anticipated payoffs from this research include: improved detection thresholds, enhancement of discrimination by location, improved capability to estimate the yields of isolated shots detonated in non-standard environments, and resolution of the basic paradox in identifying earthquakes and explosions.

PROJECT 2310, ATMOSPHERIC SCIENCES

The atmospheric sciences project provides the fundamental research needed to understand the environment in which the Air Force operates. This improved understanding will lead to better precision-guided munitions, C^3I, surveillance, and spacecraft reliability. The Air Force requirement for night/in-weather operational capability is not achievable without this fundamental understanding of atmospheric processes. Atmospheric properties such as wind, clouds, precipitation, ionization, and optical/infrared transmissivity all affect Air Force system performance. AFOSR sponsored research includes extramural contract/grants and basic research programs of Phillips Laboratory. It emphasizes improved atmospheric prediction for enhanced tactical operations and ionospheric dynamics and impacts on communications and surveillance systems.

Atmospheric Sciences

- Ionospheric Research
  - -- Understanding the Ionosphere and Its Impact
  - -- Artificially Disturbed Ionosphere
- Meteorology
  - -- Improving Weather Prediction
  - -- Lightning Prediction
  - -- Mesoscale Meteorology
  - -- Molecular and Optical Properties

Ionospheric dynamics studies seek to improve C^3I, surveillance, and spacecraft reliability. Ionospheric disturbances can interrupt communications, degrade early warning systems, and decay spacecraft orbits. The Phillips Laboratory Ionospheric Physics Division (PL/GPI) conducts most of this research which benefits operational customers such as Air Force Space Command and the Air Force Space Forecasting Center. A new explanation for strong lower wave hybrid turbulence was developed by researchers at Phillips Laboratory which has the capability to predict regions of ionospheric disturbances.

Research also focuses on the physics and dynamics of the lower atmosphere. The ultimate goal is to improve atmospheric prediction in support of tactical and strategic forces. The Phillips Laboratory Atmospheric Sciences Division conducts about one half of this research. Mesoscale weather prediction, boundary layer physics, cloud microphysics, and atmospheric electricity comprise the main research interests. The Air Force's Combat Weather System will take advantage of many

discoveries in this subarea including recent efforts to integrate satellite data into mesoscale weather forecasting models. A tri-service program of research in atmospheric and space sciences is jointly planned through the Scientific Planning Group for Atmospheric and Space Sciences.

The upcoming year will see increased focus on improving remote sensing techniques to identify cloud layers and retrieve vertical profiles of the atmosphere. Scientists will also conduct a field experiment to evaluate the structure of atmospheric electrical fields under conditions of natural and triggered lightning.

PROJECT 2311, SPACE SCIENCES

Space Sciences stimulates and supports basic research devoted the Air Force Mission to defend the United States through the control and exploitation of space. The Scientific Planning Group for Atmospheric and Space Sciences plans Tri-Service research programs in this area. The objective of Space Sciences is to define the space arena in support of present and future Air Force operations. Research in space sciences provides the basic knowledge of the particles and electromagnetic fields in near-Earth space, including solar dynamics and the interaction of particles and energy from the sun with the interplanetary medium and the Earth's magnetosphere. Solar radiation and charged atomic particles can damage and destroy Air Force spacecraft, disrupt the detection and tracking of missiles and satellites, distort communications, and interfere with surveillance operations. Space Science research is critical to the development of future Air Weather Service space weather prediction models and future Air Force space surveillance systems. This project strives to understand geomagnetic storms arising from solar disturbances. These solar disturbances are the major cause of blackouts in satellite communication systems. Unencumbered surveillance and communications require prediction and mitigation of the effects of solar emissions. Research involves both analytical and theoretical studies based on data collected from Earth-based observatories, satellite sensors, and active space experiments that seek to control the space environment. The Space Sciences project performs basic research at the Geophysics Directorate of the Phillips Laboratory and at universities throughout the United States. The hazard to space systems posed by energetic particles in the Earth's radiation belts continues to increase due to reliance on unhardened technologies and the potential of adversaries to increase trapped particle populations. Theoretical work to investigate active methods of reducing trapped particle populations will be undertaken.

Space Sciences

- Space Physics
  - -- Active Space Experimentation
  - -- Space Weather Specification and Prediction
  - -- Magnetospheric Model
  - -- Space Surveillance
  - -- Solar Activity

PROJECT 2312, BIOLOGICAL SCIENCES

This project supports two major concerns of our Air Force technology areas: force readiness and environmental protection. Biological science research provides a fundamental understanding of the biological mechanisms regulating human performance, and the response of individuals and the environment to toxic agents. This understanding is required to develop strategies to improve human performance and to protect both personnel and the environment from hazardous agents utilized in Air Force operations. Research in this project is planned through the Tri-Service Scientific Planning Groups for Environmental Quality, Biological Science, and Cognitive and Neurosciences.

Biological Sciences

- Bioenvironmental Sciences
  - -- Environmental Toxicology
  - -- Radiant Energy Bioeffects
  - -- Bioremediation
- Chronobiology and Neural Adaptation
  - -- Circadian Timing System
  - -- Aircrew Performance and Fatigue Prediction
  - -- Brain Mechanisms
  - -- Neurobiology of Attention
  - -- Biochemistry of Stress

Bioenvironmental sciences research seeks to understand fundamental mechanisms involved in

assessing and predicting both the health and environmental hazards of Air Force chemicals and the occupational health hazards of laser and microwave radiation. Studies focus on constructing predictive models to assess health and environmental risks. Ultimately, this research will contribute to the development of rapid and accurate methods that may identify environmentally safe materials and technologies during the early stages of their design and development. Early knowledge of potential toxicity will better enable the Air Force to comply with environmental laws, protect the environment, and avoid wasting time and money on the scale up and manufacture of still more toxic materials. This research also provides a scientific base within the Air Force, enabling contributions to the risk assessment process for determining the environmental and health standards of Air Force-relevant materials. Research conducted in this area has strong dual-use applications. For example, ongoing work assessing the ocular effects of ultrashort laser pulses stands to benefit not just the Air Force but the medical fields of surgery and ophthalmology as well.

The bioenvironmental sciences program also includes a research thrust involving the biodegradation and detoxification of hazardous Air Force materials. This research examines microbiological, biochemical and molecular mechanisms required to optimize use of microbes to degrade hazardous materials such as jet fuels and missile propellants. A mechanistic understanding of biodegradation will enable the development and implementation of cost-effective and environmentally safe strategies for cleaning up contaminated Air Force bases. An anaerobic bacterium discovered by Air Force researchers is now being used by Envirogen, Inc., J.R. Simplot, Inc., and the EPA to degrade nitrogen-based explosive and propellant compounds. With possible dual-use applications in the recovery of usable manufacturing materials, this effort also supports Manufacturing Technology.

Neural Adaptation research focuses on brain mechanisms underlying attention, arousal, and the biochemical effects of stress. Researchers will systematically analyze behavioral consequences of biochemical regulation of nervous system function to understand functional relationships between brain chemistry and performance. Cortex, Inc. is testing a chemical discovered in this program as a potential learning-enhancing drug. Research on the psychobiology of stress examines the biochemical response to stress, as well as determining neurochemical means for manipulating the stress response. Development of techniques to maintain optimum human performance requires determination of basic mechanisms regulating the circadian timing system during periods of disrupted natural biological rhythms. An understanding of these mechanisms will facilitate the development of pharmacological, photic and behavioral strategies for altering internal clock function and ultimately alleviate the operational performance decrements associated with jet lag and night operations.

Chronobiology research focuses on the structure and function of the biological pacemaker, including its neurochemical composition, genetic regulation, and the specificity of its cellular response to stimuli. Additional approaches involve the mechanisms which entrain the biological clock to reset, the sensory motor, and cognitive manifestations of circadian activity. Recent accomplishments include temporal correlation of neurochemical activity with circadian behavior in mammals and the fact that light exercise by humans during the later part of the subjective night phase advances the circadian clock by one hour. Additional significant results include identification of neurotransmitters released during stress and fear, as well as the identification of certain amino acids to influence synaptic transmission and thereby enhance performance. The key Air Force customers of this research are ACC, AMC, and the USAF Safety Center.

PROJECT 2313, HUMAN PERFORMANCE

This project supports the increased effectiveness of Air Force systems by improving current technologies for creating human experts and by developing new technologies that successfully mimic human expertise in automated systems. Researchers develop tests and models of human performance for sensory processing tasks (in vision, hearing, and balance) and for cognitive tasks (e.g., diagno-

sis, decision-making, and situational awareness). Tests of human performance support improved systems of selection, classification, training and human interface. Models of human performance assist in development of new human interface and machine intelligence technologies. Elements of the project include vision, hearing, spatial orientation, and cognition. Research in these areas is planned together with the Army and Navy through active participation on the Scientific Planning Group for Cognitive and Neuroscience.

Vision research supports the Air Force need to improve the effectiveness of visual displays, including camouflage, and to create novel systems for automated processing of image data. Researchers recently created and applied models of human contrast perception to problems of image quality measurement and camouflage. Models of retinal image processing derived from measures of neural circuitry in the retina are used to create novel integrated circuits for computer image processing.

Hearing research supports the Air Force need for secure error-free voice communication and improved human interface technologies that take advantage of automatic speech recognition and virtual environments. A model of acoustic signal encoding by vertebrates expresses a novel integrated circuit with potential use for hearing aids and related applications where signal shaping can increase intelligibility. A demonstrated neural network model of auditory localization can segment complex sound fields containing multiple sources. Cues to target location provided by novel 3-D audio devices improve visual search. These devices are now being tested for use by ACC.

Human Performance

→ Sensory Systems
-- Human Image Processing
-- Speech Recognition
-- Pattern Recognition
-- Multisensory Integration

→ Cognition
-- Cognitive and Psychomotor Performance
-- Individual Differences
-- Human-Machine Interaction
-- Intelligent Teaching Strategies

An understanding of multisensory integration is required to make the dynamic aviation environment safe by reducing the human sensory mismatches that result in pilot disorientation in aircraft accidents. The focus is on the integration of visual, vestibular, kinesthetic and proprioceptive information processing. Experimental and theoretical approaches involve the simultaneous examination of visual search patterns, the speed and accuracy of complex joint movements, and the underlying patterns of control necessary to assure safe flight. The USAF Safety Center and ACC are the key customers of this research.

Cognitive science supports the Air Force need to select personnel with the potential to attain high levels of expertise, and to improve the training and performance of experts working with highly automated systems. A model of individual human cognitive ability, developed from years of experimentation, compares favorably with existing selection tests. Other projects of the Armstrong Laboratory now support follow-on longitudinal studies. A neural network model of human learning and pattern classification is being used to analyze patterns in complex databases in the domains of intelligence, medical diagnosis, and seismology. An intelligent tutor, based on research from this program is now being tested by the USAF Academy and public high schools.

PROJECT 4113, SCIENCE AND ENGINEERING EDUCATION PROGRAMS

In addition to the research conducted under scientific projects, AFOSR supports programs, whose overall purpose is to stimulate scientific and engineering education and to increase the interaction between the broader research community and the Air Force laboratories. Special emphasis is placed on increasing the number of U.S. citizens with advanced degrees in science and engineering--key contributors to American industrial competitiveness and economic, as well as military, security. Full participation by minorities is an

integral objective of all our programs. AFOSR uses Defense Research Sciences (DRS) and University Research Initiative (URI) funds to support the Science and Engineering Education programs discussed in this section. URI is a DOD-wide program designed to strengthen the ability of universities to conduct research and educate scientists and engineers in technologies important to national defense. Each URI research program may include funds for graduate fellowships or grants, research instrumentation, and exchanges of scientists and engineers with other research organizations, particularly DOD laboratories. Fellowships and grants increase the number of graduate students in science and engineering. Upgrading university instrumentation enhance universities' research and education capabilities, as will scientific exchanges. The exchanges also increase contacts among universities, industry, and DOD laboratories, maximizing the contributions of defense research to the nation's military and economic security.

Summer Faculty Research Program: The SFRP stimulates new relationships with university science and engineering faculty and their professional peers in the Air Force; enhances the research interests and capabilities of scientific and engineering educators in areas of Air Force interest; and develops the basis for continuing research of Air Force interest at the faculty member's institution.

At least 150 university faculty will be selected to conduct research at Air Force laboratories for up to twelve weeks in FY 96. Upon completion, approximately 60 mini grants (up to $25K each) will be awarded in FY 96 to continue promising SFRP research efforts at the institution of the faculty member.

Graduate Student Research Program: GSRP is an adjunct to the SFRP. It permits graduate students to participate in research under the direction of a faculty member at an Air Force laboratory; stimulates professional association among graduate students, their supervising professors, and professional peers in the Air Force; furthers research objectives of the Air Force; and exposes graduate students to potential thesis topics in areas of Air Force interest.

In FY 96, approximately 100 graduate students will be selected to perform research for up to twelve weeks during the summer at Air Force laboratories.

University Resident Research Program: The URRP stimulates research cooperation between Air Force laboratories and institutions of higher education. Under the Intergovernmental Personnel Act, faculty members are brought into Air Force laboratories to conduct research for one year after which they return to their university with a broadened awareness of Air Force research needs and operations. Extension for a second year of residency is possible. For FY 96, twenty-two URRP slots are allocated to the laboratories.

USAF National Research Council (NRC) Resident Research Associateship Program: This program provides postdoctoral and senior scientists and engineers opportunities to research problems of their own choice that are compatible with the research interests of selected sponsoring Air Force laboratories. In this way, these researchers contribute to the overall research effort of the laboratories. This program is analogous to fellowships, associateships, and similar programs at the doctoral level in universities and other organizations.

The postdoctoral program is available to U.S. citizens and permanent residents and focuses on recruiting and developing America's most promising new PhD's. The senior associate positions, intended for internationally renowned researchers who have established their reputations over several years in academia, government or industry, are open to all qualified candidates of the U.S. and to citizens of other countries. Applicants must apply to the NRC and pass an NRC panel review to be considered for an award. Approximately 50 researchers will receive awards in FY 96.

National Defense Science and Engineering Graduate Fellowship Program: AFOSR participates in the National Defense Science and Engineering Graduate (NDSEG) Fellowship Program with the Army Research Office, the Office of Naval Research, and the Defense Advanced Research Projects Agency. The purpose of the program is to increase the number of U.S.

citizens trained in science and engineering of military importance. The Air force will award approximately 25 fellowships in FY 96. Ten percent of these awards are set aside for applicants who are members of ethnic minority groups underrepresented in fields of science and engineering.

GLOSSARY

ACC:	Air Combat Command
AEDC:	Arnold Engineering Development Center
AETC:	Air Education and Training Command
AFOSR:	Air Force Office of Scientific Research
AFSFC:	Air Force Space Forecasting Center
AFTAC:	Air Force Technical Applications Center
ALC:	Air Logistics Center
AMC:	Air Mobility Command
AOARD:	Asian Office of Aerospace Research and Development
ARPA:	Advanced Research Projects Agency
ASC:	Aeronautical Systems Center
ATRI:	Advanced Thermionics Research Initiative
BMDO	Ballistic Missile Defense Organization
C^3I:	Command, Control, Communications and Intelligence
CFD:	Computational Fluid Dynamics
CMC:	Ceramic Matrix Composite
CRDA:	Cooperative Research and Development Agreement
DEM:	Discrete Element Method
DRS:	Defense Research Sciences
EOARD:	European Office of Aerospace Research and Development
EPA:	Environmental Protection Agency
FJSRL:	Frank J. Seiler Research Laboratory
FY:	Fiscal Year
GSRP:	Graduate Student Research Program
HEDM:	High Energy-Density Matter
HF:	High Frequency
HPM:	High Power Microwave
INS:	Inertial Navigation System
IR:	Infrared
IR&D:	Independent Research and Development
JDL:	Joint Directors of Laboratories
JSEP:	Joint Services Electronics Program
MBE:	Molecular Beam Epitaxy
MEM:	microelectromechanical
MIT:	Massachusetts Institute of Technology
MOCVD:	Metal-Organic Chemical Vapor Deposition
NRC:	National Research Council
NDE:	Nondestructive Evaluation
NDSEGFP:	National Defense Sciences and Engineering Fellowship Program
NOAA:	National Oceanographic and Atmospheric Administration
P&W:	Pratt and Whitney
SAR:	Synthetic Aperture Radar
RCS:	Radar Cross Section
RF:	Radio Frequency
RPI:	Rennselaer Polytechnic Institute
S&T:	Science and Technology
SBIR:	Small Business Innovative Research
SFRP:	Summer Faculty Research Program
SMC:	Space and Missile Systems Center
SO:	Spatial Orientation
SPO:	System Program Office
T&E:	Test and Evaluation
TAP:	Technology Area Plan
TEO:	Technology Executive Officer
URI:	University Research Initiative
URRP:	University Resident Research Program
USAFA:	United States Air Force Academy
USWRP:	United States Weather Research Program
VLF:	Very Low Frequency
WR-ALC	Warner Robbins Air Logistics Center

INDEX

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

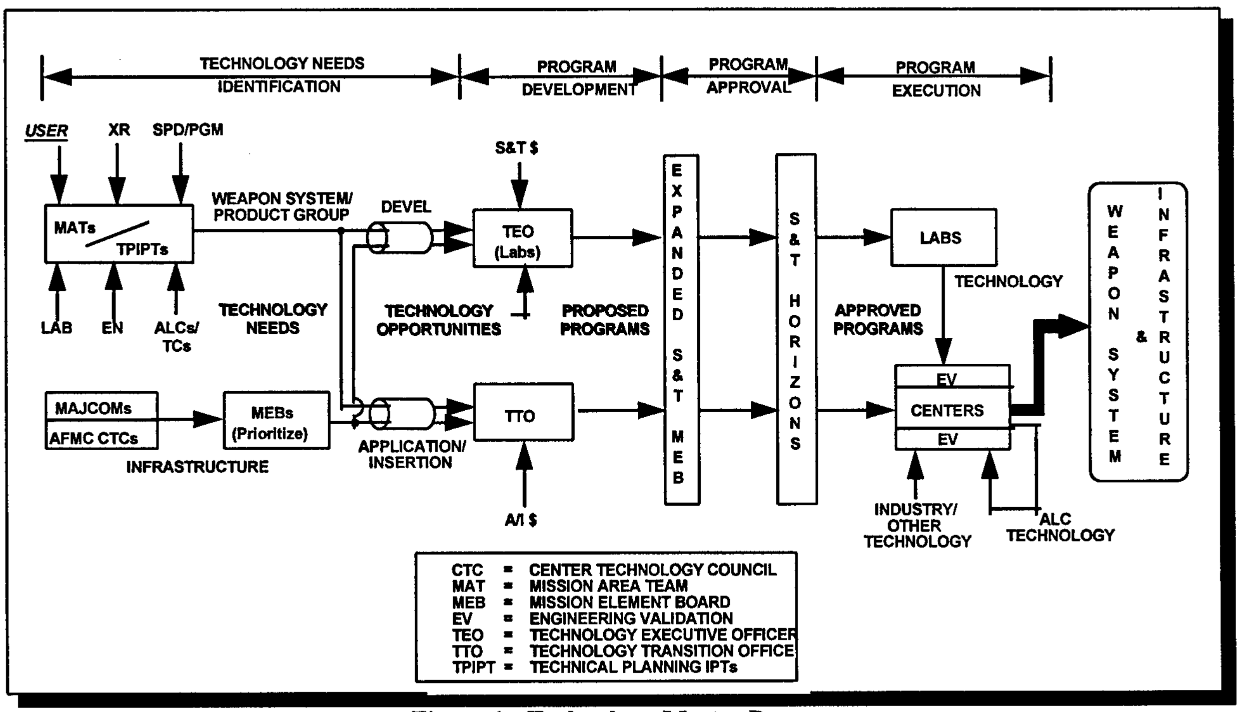


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification**--Collects customer-provided technology needs associated with both weapon systems/product groups (via TPIPTs) and supporting infrastructure (via CTCs), prioritizes those needs, and categorizes them according to the need to develop new technology or apply/insert emerging or existing technology. Weapon system-related needs are derived in a strategies-to-task framework via the user-driven Mission Area Planning process.

- Phase 2, **Program Development**--Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.

- Phase 3, **Program Approval**--Reviews the proposed project portfolio with the customer base via an Expanded S&T Mission Element Board and, later, the AFMC Corporate Board via S&T HORIZONs. The primary products of Phase 3 are recommended submissions to the POM/BES for S&T budget and for the various technology application/insertion program budgets.

- Phase 4, **Program Execution**--Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

TMP Implementation Status

The Technology Master Process is in its first full year of implementation. AFMC formally initiated this process at the beginning of FY94 following a detailed process development phase. During the FY95 cycle, AFMC will use the TMP to guide the selection of specific technology projects to be included in the Science and Technology FY98 POM and related President's Budgets.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STP, DSN 787-7850, (513) 257-7850.

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